The changes of water resources in Belarus

Alexander VOLCHAK[1], Ivan KIRVEL[2], Sergey PARFOMUK[1]

[1] Brest State Technical University, Moskovskaya 267, Brest 224017, Belarus,

e-mail: volchak@tut.by

[2]Pomeranian University in Slupsk, Partyzantów 27, 76-200 Slupsk, Poland,

e-mail: kirviel@yandex.by

ABSTRACT

The total water resources in Belarus have not changed during last years. However, the redistribution of water resources for the basins of main rivers is specified. There was an increasing of runoff for the Pripyat and Western Dvina rivers, and a decreasing of runoff for the other rivers in Belarus. The increasing of water resources of the Brest and Gomel regions is also observed. Due to the decreasing of runoff for the Neman River the Grodno region is characterized by the decreasing of water resources. The map of the mean annual runoff in Belarus was constructed.
The operational resources of underground waters in Belarus have not changed. At the same time the increasing of explored operational resources of underground waters over 10 years period by the value 287.92 m3/day was investigated. The analysis of the explored water resources has found that the groundwater resources of categories A and B were increased, C1 was decreased, and the C2 resources decreased from 466.5 to 61 m3/day.
The analysis of the main indicators of hydrochemical regime has shown the reducing pollution for the rivers in Belarus. At the same times we can say that the quality of surface water is still not satisfactory for the Svisloch, Yaselda, Berezina, Dnieper, and Neman rivers.

Key words: runoff, water resources, surface resources, groundwater, hydrochemical regime.

INTRODUCTION

Belarus currently has 20781 rivers, about 11 thousand lakes, 153 water basins, and 1306 small basins, and also 19 state fish farms. The total length of the rivers is 90631 km. However, 19291 of the rivers (about 80%) are the small rivers with length less than 10 km. The mean density of the river network is 0.44 km/km2. Maximum values are typical for the North of the country, where this value is 0.60-0.80 km/km2. The minimum value of 0.23 and 0.30 km/km2 in observed in the South of Belarus. About 45% of Belarusian rivers are the rivers of the Baltic Sea basin, and 55% are the rivers of the Black Sea basin. The hydrographical map of Belarus is presented in Figure 1

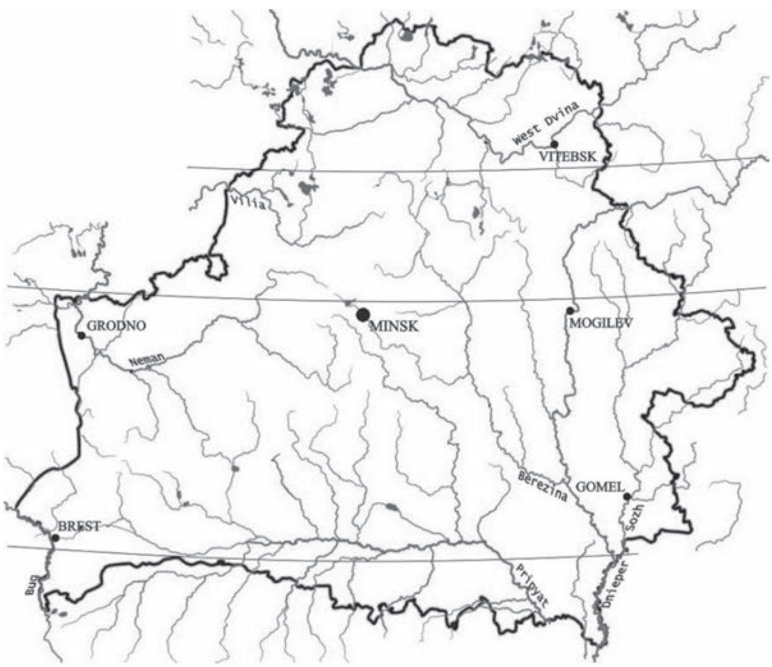

Fig. 1. The hydrographical map of Belarus

Due to the properties of climatic conditions, from 146 km3 annual precipitation 110 km3 evaporates into the atmosphere and only 34 km3 recycled into drainage areas, which is only 25%. The 25.7 km3 of runoff per year comes from neighboring territories, so the total runoff is 56.9 km3 per year. In a year of low water level when, the runoff might be 37.5 km3.

The last fundamental work of calculating the water resources in Belarus was published in 1996 (Pluzhnikov et al., 1996). In this paper the period of data ended in the second half of the 1980's and not included the modern period of warming climate. Over the years water resources of Belarus were subjected to transformation due to the effects of natural and anthropogenic factors. The problem of preserving the quality of water resources is also very important.

Earlier the authors have performed the analysis of climate change on water resources in Belarus (Volchak, Parfomuk, 2014). The aim of the current work is the continuation of research and modern quantitative analysis of surface and ground water resources in Belarus. Another goal is the investigating of the problem of transformation of hydrochemical regime for the water resources according to basic indicators.

DATA SOURCE AND RESEARCH METHODS

The data sources are based on the materials of the Hydrometeorology Department of the Ministry of natural resources and environmental protection of the Republic of Belarus according to 122 hydrological stations. To obtain comparable the results we selected single 50-years period since 1964 till 2013.

For the analysis of transformation of hydrochemical regime we used data for the period since 1999 till 2010. We analyzed the changes in the following indicators: content in water of dissolved oxygen, nickel, petroleum, iron, copper, zinc, phosphate, nitrite nitrogen, ammonia nitrogen, synthetic surface-active substances (surfactants), index of pollution, biochemical oxygen demand 5 days (BOD5).

To assess the transformation of hydrochemical regime of the rivers the linear and non-linear trends were used, than the statistical significance was determined.

RESULTS

The natural water resources for the basins of major rivers and administrative areas in Belarus were calculated for the period 1964-2013. The results of the research and the changes to the data presented in (Pluzhnikov et al., 1996) are given in Table 1 and 2.

The total surface resources in Belarus have not changed. At the same time, there was a redistribution of natural water resources for the basins of the various rivers. The increasing of runoff for the Pripyat and West Dvina rives was found. The decreasing of surface water resources for the other river systems of the country in recent years was observed (Volchak, Parfomuk, 2014).

The increasing of water resources for the Brest and Gomel regions was calculated. The Grodno region is characterized by the decreasing of runoff due to the reduction in the water level of the Neman River. These changes in the river runoff in modern conditions are based mainly on the increasing of the intensity of the atmosphere circulation, which is clearly demonstrated in (Loginov, Volchak, 2006).

Table 1.
The natural water resources for the basins of major rivers in Belarus for the period 1964-2013(numerator), and its changes to the data presented in (Pluzhnikov et al., 1996) (denominator)

River basin	River runoff, km^3/year									
	Local					General				
	Probability, %					Probability, %				
	5	25	50	75	95	5	25	50	75	95
West Dvina	10.6	7.8	6.9	5.5	4.4	22.3	16.4	14.1	11.6	9.0
	0.1	0.1	0.1	0.0	0.1	0.4	0.2	0.2	0.3	0.4
Neman	8.0	6.7	6.2	5.4	4.9	8.1	6.8	6.3	5.5	5.0
	-0.5	-0.4	-0.4	-0.5	-0.3	-0.5	-0.4	-0.4	-0.5	-0.3
Vilia	2.9	2.4	2.1	1.8	1.4	2.9	2.4	2.1	1.8	1.4
	-0.3	-0.3	-0.2	-0.2	-0.4	-0.3	-0.3	-0.2	-0.2	-0.4
Bug	2.8	1.6	1.3	0.9	0.7	2.8	1.6	1.3	0.9	0.7
	-0.2	-0.2	-0.1	-0.2	-0.1	-0.2	-0.2	-0.1	-0.2	-0.1
Pripyat	11.2	7.6	6.6	5.0	3.5	23.9	16.8	14.4	11.0	8.3
	1.3	1.1	1.0	0.6	0.4	1.7	1.5	1.4	0.9	1.3
Dnieper	16.3	11.8	11.0	9.5	7.8	28.2	20.3	18.7	15.6	13.1
	-0.1	0.1	-0.3	0.1	0.2	0.0	0.1	-0.2	-0.1	0.3
including:										
Berezina	6.3	5.0	4.5	4.0	3.4	6.3	5.0	4.5	4.0	3.4
	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.1
Sozh	4.9	3.4	3.0	2.4	1.8	10.6	7.6	6.6	5.4	4.4
	-0.1	-0.1	0.0	-0.1	-0.2	0.0	0.1	0.2	0.2	0.1
Total area	**51.8**	**37.9**	**34.1**	**28.1**	**22.7**	**88.2**	**64.3**	**56.9**	**46.4**	**37.5**
	0.3	**0.4**	**0.1**	**-0.2**	**-0.1**	**1.1**	**0.9**	**0.7**	**0.2**	**1.2**

Table 2.
The natural water resources for the administrative regions in Belarus for the period 1964-2013 (numerator), and its changes to the data that published in (Pluzhnikov et al., 1996) (denominator)

c	River runoff, km^3/year				
	Probability, %				
	5	25	50	75	95
Brest	7.5	4.8	4.2	3.3	2.4
	0.3	0.2	0.2	0.1	0.0
Vitebsk	12.4	9.0	8.1	6.6	5.2
	0.1	0.0	0.1	0.0	0.0
Gomel	9.3	6.6	5.9	4.9	3.7
	0.4	0.3	0.3	0.3	0.2
Grodno	5.6	4.7	4.4	3.8	3.6
	-0.4	-0.3	-0.3	-0.4	-0.2
Minsk	9.9	7.6	6.7	5.4	4.5
	-0.1	0.1	0.0	-0.2	-0.1
Mogilev	7.1	5.2	4.8	4.1	3.3
	0.0	0.1	-0.2	0.0	0.0
Total area	**51.8**	**37.9**	**34.1**	**28.1**	**22.7**
	0.3	**0.4**	**0.1**	**-0.2**	**-0.1**

Earlier there were constructed several maps of the mean annual runoff for the rivers in the territory of Belarus: in 1966 (Surface water resources, 1966), in 2000 (The handbook, 2000), and in 2002 (The Belarusian encyclopedia, 2002). The last map is shown in the Figure 2. For the purpose of updating the water resources of Belarus, the new map of the mean annual runoff for rivers in Belarus for the period till 1964 since 2013 was constructed. This map is presented in Figure 3.

The initial data for the map shown in Figure 3 based on the period 1964–2013 for the current hydrological stations. The number of used stations is enough to the correct displaying information for the annual runoff in the territory of Belarus (Loginov et al., 2006). Using of modern computer techniques for mapping the mean annual runoff was possible to eliminate the subjectivity of the authors. Shown in Figure 3 map represents the optimal combination of several methods of maps constructing with using different interpolation methods and performed in different computer systems. Availability of required number of hydrological stations for runoff, the single observation period and using of computer technology has allowed obtaining an objective map of the mean annual runoff for the rivers in Belarus in modern conditions.

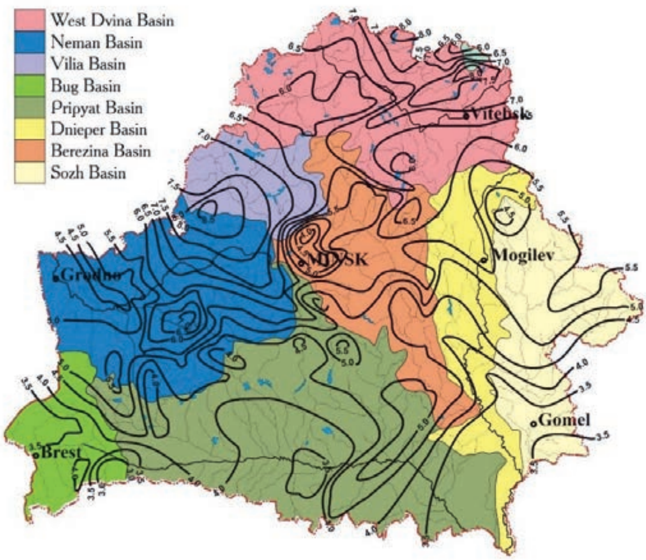

Fig. 2 The map of the mean annual runoff in Belarus (2002), l/(s · km2) (The Belarusian encyclopedia, 2002).

Comparative analysis of the maps of mean annual runoff constructed for the different periods confirmed the data given in Table 1. The Western Dvina River is characterized by a negligible increasing of runoff. For the basins of the Neman and Vilia rivers the decrease of runoff is found. According to the Belarusian Polesie the contour line of runoff with a value of 4 is investigated, rather than value of 3.5 as it was before. That results show an increasing of runoff for the rivers of the Pripyat River basin. For the Dnieper River and its major tributaries (the Berezina and Sozh rivers) as well as for the Bug River identified both decreasing and increasing of the mean annual runoff.

There is centralized water supply of settlements and industrial enterprises in Belarus. It based on using the groundwater and surface water. At the same time using of fresh groundwater is the only source of drinking water in some regions. Table 3 shows the operational resources and explored reserves of groundwater in Belarus for the river basins and administrative areas for the 2010 year (The state, 2011).

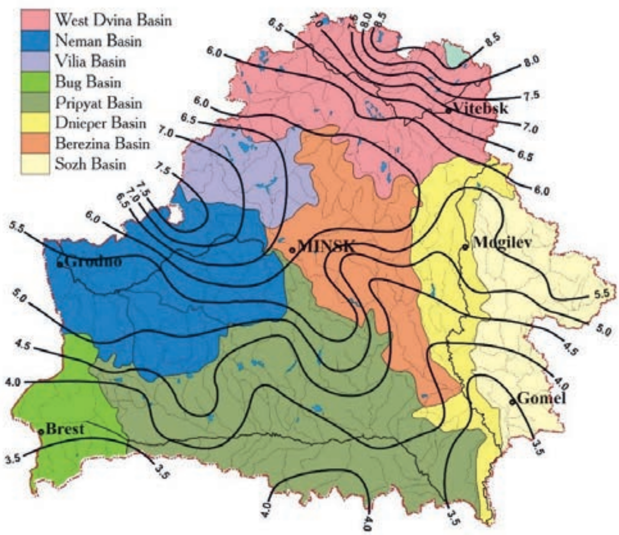

Fig. 3 The map of the mean annual runoff in Belarus for the period 1964-2013, l/(s·km2).

Table 3.
The operational resources and explored reserves of underground waters for the river basins and administrative areas in Belarus for the 2010 year (The state, 2011)

Administrative regions and river basins	Operational resources of underground waters, thousand m³/day	Reserves of groundwater by the categories, thousand m³/day				
		A (developed)	B (explored)	C1 (estimated)	C2 (discovered)	total
River basins						
West Dvina	8141.2	332.30	228.70	194.80	–	755.80
Neman	9629.3	452.56	491.64	209.50	10.0	1163.70
Vilia	4589.0	134.00	125.30	40.10	–	299.40
Bug	1813.3	205.25	122.65	22.20	–	350.10
Pripyat	10278.4	508.10	394.30	122.70	41.0	1066.10
Dnieper	15144.8	1612.60	987.20	372.12	10.0	2981.92
including:						
Berezina	6585.6	385.91	302.45	90.80	–	779.16

Admin-istrative regions and river basins	Operational resources of under-ground waters, thou-sand m³/day	Reserves of groundwater by the categories, thousand m³/day				
		A (developed)	B (explored)	C1 (estimated)	C2 (discovered)	total
Svisloch	712.0	379.40	247.70	52.60	–	679.70
Sozh	3316.7	320.46	287.90	122.40	–	730.76
Total area	**49596.0**	**3244.81**	**2349.79**	**961.42**	**61.0**	**6617.02**
Administrative regions						
Brest	5603.4	435.05	337.95	81.10	41.0	895.10
Vitebsk	9549.9	419.88	270.40	228.02	–	918.30
Gomel	8477.2	568.10	381.00	133.10	10.0	1092.20
Grodno	7687.5	299.90	324.50	135.90	–	760.30
Minsk	11945.0	975.86	822.44	235.30	10.0	2043.60
Mogilev	6333.0	546.02	213.50	148.00	–	907.52
Total area	**49596.0**	**3244.81**	**2349.79**	**961.42**	**61.0**	**6617.02**

Comparing with the data in paper (Pluzhnikov et al., 1996) has shown that the operational resources of underground waters have not changed. At the same time the increasing of explored reserves of groundwater by the value of 287.92 m3/day was found. The general tendency is the increasing of stocks, but the exception is the basin of the Dnieper River and especially the basin of the Svisloch River. This river is characterized by the decreasing of explored reserves of groundwater by the value of 632.1 m3/day or 48.2 % compared with the data in work (Pluzhnikov et al., 1996). When analyzing the transformation of the explored reserves by the categories we have found that the groundwater reserves of categories A (developed) and B (explored) increased, C1 (estimated) – insignificant decreased, and the C2 (discovered) reserves decreased from 466.5 to 61 m3/day.

The last part of the research was studying the transformation of hydrochemical regime for the rivers. For this purpose, the gradients of change of annual mean concentrations of priority substances in the water for the rivers of Belarus in 1999-2010 were investigated. Changes of annual mean concentrations of ammonia nitrogen are mixed, although dominated the trends of increasing pollution. The increasing of the concentration of ammonium nitrogen is statistically significant for the Svisloch (the highest contamination), Dnieper and Yaselda rivers. The pollution for the other river is rather less.

The nitrogen nitrite pollution for the all rivers tends to decrease. A similar situation is observed for the petroleum products, but this decreasing was statistically significant only for the Yaselda and Mukhavets rivers.

The decreasing of the pollution index was found for the all stations, except the Svisloch River. The increasing of zinc and nickel is observed. The decreasing of dissolved oxygen is typical for the most water stations, but the most decreasing is observed for the Neman River. The content of iron and copper in surface waters is ambiguous. The statistically significant gradients of increasing are found for the two stations (the Pripyat and Yaselda rivers). These metals have a high content in the waters of a natural character. There was the decreasing of BOD5 for the most stations, and the Yaselda River has statistically significant trend of decreasing. Statistically significant decreasing of surfactants is calculated for the West Dvina River, and the Mukhavets and Pripyat rivers have the increasing of surfactants (Volchak, Volchak, 2007).

CONCLUSIONS

A quantitative assessment of water resources in Belarus is carried out. The redistribution of surface water resources in the basins of major rivers and administrative areas was investigated, while the total natural resources of river waters of the country have not changed. The statistically significant increasing in the explored reserves of groundwater resources compared to the 1996 was found. The changes of river runoff and hydrological regime in modern conditions are caused by the increasing of the intensity of the general circulation of the atmosphere.

The new map of the mean annual runoff of rivers in Belarus was constructed. This map can be used for determining the parameters for the different small rivers without input data.

During the analyzing of hydrochemical regime transformation of surface waters for basic parameters the decreasing of pollution for rivers in Belarus was found, but still the quality of surface water for the Svisloch, Yaselda, Berezina, Dnieper, and Neman rivers is not satisfactory.

REFERENCES

Loginov V., Volchak A. (2006), *The water balance of river basins of Belarus*, Minsk, p. 160.

Loginov V., Volchak A., Volchak An., Parfomak S. (2006), Optimization of a hydrological network of Belarus., *Nature Management,* 12, Minsk, pp. 51–57.

Pluzhnikov V, Fadeeva M., Bachurin V. (1996), Water resources of Belarus, their use and conservation, *Natural resources*, 1, pp. 24–29.

Surface water resources of the USSR. Belarus and the basin of Upper Dnieper, (1966), Leningrad, p. 718.

The Belarusian encyclopedia, (2002), Minsk, p. 552

The handbook to construction norms and rules P1-98 to SNiP 2.01.14-83, (2000) *Determination of design hydrological characteristics*, Minsk, p. 174.

The state water cadastre. Water resources, their use and quality of waters (2010), Minsk, p. 109.

Volchak A., Volchak An. (2007), Transformation of the surface water quality of rivers of Belarus, *Brest State Technical University*, 44, pp. 5–16.

Volchak A., Parfomuk S. (20140, Influence of climate change on water resources in Belarus. In: A. Witkowski, J. Harff, M. Reckerman (eds.) *The environmental and socio-economic response in the southern Baltic region,* 6nd International Conference on Climate Change proceedings, Szczecin, Poland, 12-15 May 2014, pp. 73–74.